

भारतीय मानक

IS 3703 : 2023

Indian Standard

(Amalgamating IS 3703 : 2004,
IS 10543 : 1983 & IS 12147 : 2013)

चुम्बकीय कण दोष संसूचन की रीति संहिता (तीसरा पुनरीक्षण)

Recommended practice for magnetic particle flaw detection (Third Revision)

ICS 19.100

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फ़र मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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FOREWORD

This Indian Standard (Third Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Non-Destructive Sectional Committee had been approved by the Metallurgical Engineering Division Council.

This Indian Standard was first published in 1966 and subsequently revised in 1980 and 2004. The second revision was published under the modified title 'Recommended practice for magnetic particle flaw detection' and modified scope. In the second revision the clause on optimum sensitivity was added and clause on different types of magnetic field was modified.

While reviewing the standard the committee felt to revise this standard keeping in view the latest development in the field of magnetic particle flaw detection. The current revision supersedes IS 3703 : 2004 'Recommended practice for magnetic particle flaw detection(second revision)', IS 10543 : 1983 'Method for dry powder magnetic particle testing' and IS 12147 : 2013 'Recommended practice for wet magnetic particle examination (*first revision*)'.

In the present revision, following major modifications have been made:

- a) For achieving the optimum condition for carrying out magnetic particle flaw detection, the levels of magnetic flux density has been modified in **8.5**;
- b) Amperage values have been deleted as these values are often confusing and not practical;
- c) Formulae for magnetic field strength calculation have been added in **11.2**;
- d) Flash point (closed cup) has been increased to 93 °C, *Min* for more safety;
- e) New clause related to dry powder application has been added and the clause for wet powder application has been modified taking care of adequate requirements;
- f) The limits of illumination of light used for inspection of flaws have been increased in case of both fluorescent and non-fluorescent inks/powders in **14.7**; and
- g) The recommended practices pertaining to dry and wet magnetic particle testing have been included which were previously covered separately in IS 10543 : 1983 'Method for dry powder magnetic particle testing' and IS 12147 : 2013 'Recommended practice for wet magnetic particle examination (*first revision*)'.

Magnetic particle flaw detection is used to locate cracks, discontinuities, non-metallic inclusion and segregation at or just below the surface in ferromagnetic material. However, the method cannot be used on non-magnetic material. It is hoped that the use of this recommendation would help in establishing a unified practice for magnetic particle testing within the country.

This standard does not cover the acceptance criteria for magnetic particle testing which should be subject to mutual agreement between the contracting parties.

Examination according to this standard can be carried out on all ferromagnetic objects in the raw material stage as well as in the semi-finished/finished stages of the components/assemblies made out of such raw materials.

This method of flaw detection is not recommended in such case where the subsequent process/end-use of the objects does not permit the presence of even slightest residual magnetism. This practice covers the principle of testing applicable for both dry and wet methods. It briefly covers the methods and types of fields induces in the part to be tested as per its configuration. It suggests the equipment for generating the fields and the empirical formulae and guidelines for the current requirements. Advantages and limitations of ways of magnetizing various configurations of components are presented in tabular form. Also, applications of various types of detection media are mentioned.

The composition of the committee responsible for the formulation of this standard is listed in Annex A.

In reporting the result of a test or analysis made in accordance with this standard, is to be rounded off, it shall be done in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard***RECOMMENDED PRACTICE FOR MAGNETIC PARTICLE
FLAW DETECTION***(Third Revision)***1 SCOPE**

1.1 This standard specifies techniques and recommended procedure for both dry and wet magnetic particle flaw detection, a non-destructive testing method, for detecting cracks and other discontinuities which are open to surface or just below the surface in ferromagnetic materials. The method is applicable only to material which can be easily magnetized notably iron, steel, cobalt, nickel and their alloys. Techniques described may be applied to raw materials, semi-finished material, finished material and welds regardless of heat treatment.

1.2 This practice may be used to prepare procedures for magnetic particle flaw detection of materials and parts.

2 REFERENCES

For following standard contains provisions which through reference in this text, constitutes provisions of this standard. At the time of publication, the edition was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged investigating the possibility of applying the most recent edition of the standard listed below:

<i>IS No.</i>	<i>Title</i>
IS 3415 : 1998	Glossary of terms used in magnetic particle flaw detection (<i>second revision</i>)
IS 6410 : 2013	Magnetic flaw detection inks and powders — Specification (<i>second revision</i>)
IS 13805 : 2004	General standard for qualification and certification of non-destructive testing personnel — Specification (<i>first revision</i>)

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 3415 shall apply.

4 QUALIFICATION AND CERTIFICATION OF PERSONNEL

Non-destructive testing (NDT) personnel shall be qualified and certified as per IS 13805 or equivalent standard. The practice or standard used and the

applicable revision shall be specified in the contractual agreement between parties.

5 PRINCIPLE OF TEST

The magnetic particle method is based on the principle that magnetic lines of forces, when present in a ferromagnetic material will be distorted by a local change in the permeability due to the presence of any discontinuity having permeability different to that of the test piece. These distorted magnetic lines of forces result in leakage flux which leaps through air from one side of the discontinuity to the other side creating magnetic north and south poles at these points of exit and re-entry respectively. If finely divided ferromagnetic particles are applied to the surface of the test piece, they are attracted by these poles to form a pattern of the discontinuity.

6 DRY AND WET TECHNIQUES

Depending upon the type of ferromagnetic particle, whether free flowing dry powder or suspension of powder in a suitable liquid medium, the method is classified into dry and wet magnetic particle flaw detection respectively.

7 METHOD

In the application of the method, the following essential steps are involved:

- The part must be properly magnetized;
- Suitable magnetic particles must be applied over the surface of the part in such a way that they can move to collect at leakage fields occurring at discontinuities; and
- Any accumulation of magnetic particles must be observed and interpreted.

8 TYPES OF MAGNETIC FIELDS

The magnetic force can be produced by means of either the magnetic effect of electric current or by the magnetic fields of a permanent magnet. Depending upon the types of magnetizing methods used, generally three types of magnetic fields are produced:

- Circular magnetization;
- Longitudinal magnetization; and
- Multidirectional magnetization.

8.1 Circular Magnetization

In this method, electric current is passed through a part or by use of a central conductor through a central opening in the part, inducing a magnetic field at right angles to the current flow. The magnetic field is essentially contained within the contours of the part (*see* Fig. 1).

8.2 Longitudinal Magnetization

When electric current is passed through a multi-turn coil (either rigid or cable formed) which encloses the part or section of the part to be examined a longitudinal field parallel with the axis of the coil is induced in the part. Longitudinal magnetization is also known as bi-polar magnetization (*see* Fig. 2).

8.3 Multi-Direction Magnetization

It is not possible to have more than one direction of magnetic field present in a part at any given time. However, in multi-direction magnetization method, magnetic fields having different directions may be induced in the part in very rapid sequence, following each so rapidly that magnetic particles attracted by one field do not have time to fall away before the field is repeated. In this method, magnetic field is made to oscillate, or move, within the part from one direction to another, usually approaching 90° , which permits build-up of indications in more than one direction.

9 OPTIMUM SENSITIVITY

9.1 Direction of Field

Maximum sensitivity is achieved when the flaw lies at right angles to the magnetic flux, but the

sensitivity is not reduced below the effective level if the flaw is oriented at an angle of up to 45° from the optimum direction. Beyond 45° , the sensitivity is diminished apparently. For this reason, the complete examination of any surface requires the flux to be passed in two direction at right angle to each other in separate operation.

9.2 Type of Field

Type of magnetic field is also an important factor while considering the sensitivity. For a given magnetizing force, a stronger circular field is produced than if it were producing a longitudinal field.

This is due to the circular field being completely contained within the part, which has a low reluctance path. The longitudinal field must use an air path to return from north pole to south pole. Hence a high reluctance path. Further, the external poles of a longitudinal field attracts magnetic particles and produce confusing indications. Adequate inspection in the vicinity of such poles is impossible. For these two reasons the circular method of magnetization is preferred whenever it can be used.

9.3 Location of Flaw

If a flaw is open to the surface, the flux leakage, therefore sensitivity will be a maximum for a given size and shape of discontinuity. When a flaw is below the surface, flux leakage diminishes giving diffused indications. For sub-surface flaw, sensitivity decreases rapidly with the depth of the flaw below the surface.

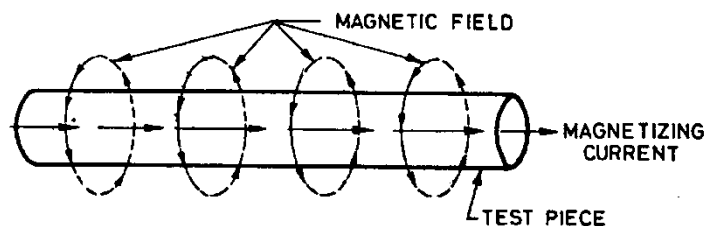


FIG. 1 CIRCULAR MAGNETIZATION OF A TEST PIECE THROUGH WHICH A MAGNETIZING CURRENT PASSES

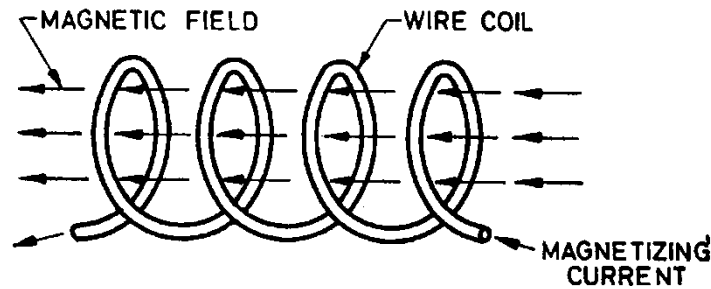


FIG. 2 LONGITUDINAL MAGNETIC FIELD WITHIN A CURRENT-CARRYING MAGNETIZING COIL

9.4 Surface Coatings

It is possible to inspect components that have been treated with a non-magnetic coating (that is, cadmium plate or paint) not greater than 50 mm thick, with only slight loss in sensitivity.

9.5 Magnetic Field Strength

The lines of force must be of sufficient strength to indicate those discontinuities which are unacceptable, yet must not be so strong that an excess of particles is accumulated locally (known as furring), thereby masking relevant indications. This optimum condition can be achieved if the magnetic particle flaw detection is carried out at levels of magnetic flux density should be between 30 Gauss to 60 Gauss ($30 \text{ to } 60 \times 10^{-4} \text{ T}$).

10 TYPES OF MAGNETIZING CURRENTS

10.1 The three basic types of current used in magnetic particle examination to establish part magnetization are alternating current (AC), single phase half-wave rectified alternating current (HW) and three phase full-wave rectified direct current (FWDC). The inductance associated with AC results in the 'skin effect' that confines the magnetic field to the surface of a part. In contrast, both HW and FWDC produce a magnetic field having maximum penetrating capabilities and are used when near surface discontinuities of concern.

10.1.1 Part magnetization with alternating current is limited to those applications where examination requirements call for the detection of discontinuities that are open to the surface. Alternating current is also extensively used for the demagnetization of parts after examination. The through coil technique is normally used for this purpose due to its simple, fast nature.

10.1.2 Direct Current

Years ago, batteries and DC generators were used to produce a magnetizing current and were used for relatively small operations. They have given way, however, to HW and FWDC.

10.1.3 Half-Wave Rectified Current

Half-wave rectified alternating current is used primarily with prod type examination but is also applicable to examinations involving both coil and through current techniques. When used in conjunction with dry powder, its pulsating characteristics provides an additional degree of mobility to the particles giving a great deal of sensitivity to sub-surface type discontinuities. It is usually associated with portable and mobile type equipment, although it is sometimes incorporated into the design of horizontal wet particle units.

10.1.4 Full-Wave Rectified Current

Full wave rectified current (FWDC) may use single as well as three phase current. As a source of part magnetization, FWDC is applicable for the detection of both surface and near surface discontinuities. This type of magnetic particle testing equipment (wet horizontal or stationary power packs) provides the high magnetizing currents necessary for the magnetic particle inspection of large components such as castings and forgings.

11 PART MAGNETIZATION TECHNIQUES

11.1 A part can be magnetized either directly or indirectly. For direct magnetization, the magnetizing current is passed directly through the part creating a circular magnetic field in the part. With indirect magnetization technique, a magnetic field is induced in the part, which can create a circular, longitudinal, or multi-directional magnetic field in the part.

11.2 The choice of direct or indirect magnetization will depend on such factors as size, configuration, or ease of processing. Table 1 compares the advantages and limitations of the various methods of part magnetization.

11.2.1 Direct Contact Magnetization

For direct magnetization, physical contact must be made between the ferromagnetic part and the current carrying electrodes connected to the magnetizing power source. Both localized magnetization and

overall part magnetization are direct contact means of part magnetization achieved through the use of prods, head and tailstock, clamps and magnetic leeches.

11.2.1.1 Localized area magnetization

a) Prod technique

The prod electrodes (generally solid copper or braided copper tips) are first pressed firmly against the test part. The magnetizing current is then passed through the prods and into the area of the part in contact with the prods. This established a circular magnetic field in the part around and between each prod electrode, sufficient to carry out a local magnetic particle examination (*see Fig. 3*).

- 1) Alternating current limits, the prod technique to the detection of surface discontinuities. Half-wave rectified direct current is most desirable since it will detect both surface and near surface discontinuities. The prod technique generally utilizes dry magnetic particle materials due to better particle mobility. Wet magnetic particles, however, are not generally used with the prod technique because of potential electrical and flammability hazards.
- 2) Proper prod examination entails a second placement with the prods rotated approximately 90° from the first placement to assure that all existing discontinuities are revealed. Depending on the surface coverage requirements, overlap between successive prod placements may be necessary.

CAUTION: Extreme care should be taken to maintain clean prod tips to minimize heating at the point of contact and to prevent arcing strikes and local overheating on the surface being examined since these may cause adverse effects on material properties. Steel or aluminium or copper braided tip prods or pads rather than the solid copper tip prods

are recommended where the possibility of copper penetration exists. Open circuit voltage should not exceed 25 V.

- 3) A remote-control switch, which may be built into the prod handles, should be provided to permit the current to be turned on after the prods have been properly placed and to turn it off before the prods are removed in order to minimize arcing.

b) Manual clamp/magnetic leech technique

Local areas of complex component may be magnetized by electrical contact manually clamped or attached with magnetic leeches to the part. As with prods, sufficient overlap may be necessary if testing of the contact location is required.

11.2.1.2 Overall magnetization

a) Head and tailstock contact

Parts may be clamped between two electrodes (such as a head and tailstock of horizontal wet magnetic particle equipment) and the magnetizing current applied directly through the part. The size and shape of the part will determine whether both field directions can be obtained with such equipment (*see Fig. 4*).

b) Clamps

The magnetizing current may be applied to the test parts by clamping the current carrying electrodes to the part producing a circular magnetic field.

c) Multi-directional magnetization technique

With suitable circuitry, it is possible to produce a multi-directional (oscillating) field in a part by selectively switching the magnetic field within the part between electrode contacts/clamps positioned approximately 90° apart. The wet method technique is generally employed.

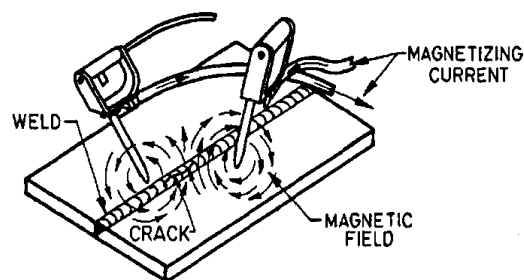


FIG. 3 CIRCULAR MAGNETIZATION WITH PROD TYPE CONTACTS

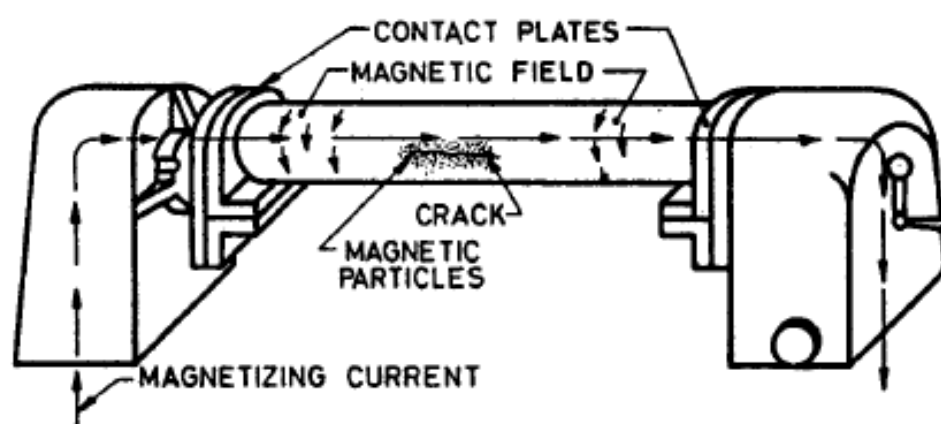


FIG. 4 CIRCULAR MAGNETIZATION OF TEST PIECE BY PASSING ELECTRIC CURRENT THROUGH THE TEST PIECE FROM MACHINE CONTACT PLATES

Table 1 Advantage and Limitations of the Various Ways of Magnetizing a Part
(Clauses 11.2 and 15.1.1)

Types of Magnetization and Part Details (1)	Advantages (2)	Limitations (3)
I. Direct Contact Part Magnetization		
A. Head/Tailstock Contact		
i) Solid, relatively small parts (Castings, forgings, machined) that can be processed on a horizontal wet unit	i) Fast and easy technique ii) Complete circular magnetic field iii) Good sensitivity to surface and near surface discontinuities iv) Simple as well as relatively complex parts can usually be easily processed v) Complete magnetic path is conducive to maximizing residual characteristics of material	i) Possibility of arcing exists If proper contact conditions are not made ii) Long parts should be magnetized in sections to facilitate bath application without resorting to an overly long current shot
ii) Large casting and forgings	Large surface areas can be processed and examined in relatively short time	High amperage requirements dictates special DC power supply
iii) Tubular-type parts such as tubing, pipe, hollow shafts, etc	i) Entire length can be circularly magnetized by contacting end to end ii) Ends must be conducive to electrical contact and capable of carrying required current without excessive heat	Effective field limited to outside surface and cannot be used for inside diameter examination
iv) Long solid parts such as billets, bars, shafts etc	i) Entire length can be circularly magnetized by contacting end to end ii) Current requirements are independent of length iii) No end loss	i) Voltage requirement increases as length increases due to greater impedance of cable and part ii) Ends must be conducive to contact and capable of carrying required current without excessive heat
B. Prods		
i) Welds	i) Circular field can be selectively directed to weld areas by prod placement ii) In conjunction with HW current and dry powder provides excellent sensitivity to sub surface discontinuities as well as surface type iii) Flexible, in that prods, cables and power packs can be brought to test site	i) Only small area can be tested at one time ii) Arcing due to poor contact iii) Surface must be dry when dry powder is being used iv) Prod spacing must be in accordance with magnetizing current level

Table 1 (Continued)

Types of Magnetizations and Parts Detail (1)	Advantages (2)	Limitations (3)
ii) Large castings or forgings	i) Entire surface area can be examined increments using nominal current values ii) Circular field can be concentrated in specific areas that historically are prone to discontinuities iii) Equipment can be brought to the location of parts that are difficult to move iv) In conjunction with HW current and dry powder provides excellent sensitivity to near surface sub-surface type discontinuities that are difficult to locate by other methods	i) Coverage of large surface areas require a multiplicity of shots that can be time consuming. ii) Possibility of arc strike due to poor contact. iii) Surface should be dry when dry powder is being used.
II. Indirect Part Magnetization		
A. Central Conductor		
i) Miscellaneous parts having holes through which a conductor can be threaded such as: 1) Bearing race 2) Hollow cylinder 3) Gear 4) Large nut 5) Large clevis 6) Pipe coupling	i) No electrical contact to part and possibility of arcing is eliminated ii) Circumferentially directed magnetic field is generated in all surfaces surrounding the conductor (inside diameter, outside diameter, faces etc) iii) Ideal for those cases where the residual method is applicable. Light weight parts can be supported by the central conductor. Multiple turns may be used to reduce current required.	i) Size of conductor must be ample to carry required current ii) Ideally, conductor should be centrally located within hole iv) Larger diameters require repeated magnetization with conductor against inside diameter and rotation of part between processes. Where continuous magnetization technique is being employed Inspection is required after each magnetization
ii) Tubular type parts such as: 1) Pipe 2) Tubing 3) Hollow shaft	i) No electrical contact of part required. ii) Inside diameter as well as outside diameter examination iii) Entire length of part circularly magnetized	Outside diameter sensitivity may be somewhat diminished relative to inside diameter for large diameter and extremely heavy wall
iii) Large valve body and similar parts	Provides good sensitivity for detection of discontinuities located on internal surfaces	Outside diameter sensitivity may be somewhat diminished relative to inside diameter for large diameter and extremely heavy wall

Table 1 (Continued)

Types of Magnetization and Part Details (1)	Advantages (2)	Limitations (3)
B. Coil/Cable Wrap		
i) Miscellaneous medium sized parts where the length predominates such as crank shaft.	All generally longitudinal surfaces are longitudinally magnetized to effectively locate transverse discontinuities	Length may dictate multiple shot as coil is repositioned
ii) Large castings, forgings or shafting	Longitudinal field easily attained via cable wrapping	Multiple magnetization required due to configuration of part
iii) Miscellaneous small parts	i) Easy and fast, especially where residual magnetization is applicable ii) Non-contact iii) Relatively complex parts can usually be processed with same ease as those with simple cross section	i) L/D (length/diameter) ratio important consideration in determining adequacy of ampere-turns ii) Effective LD ratio can be altered by utilizing pieces of similar cross-sectional area iii) Use smaller coil for more intense field iv) Sensitivity diminishes at ends of part due to general leakage field pattern v) 'Quick break' desirable to minimize end effect on short parts with low L/D ratio
C. Induced Current Fixtures		
i) Examination of ring shaped part for circumferential-type discontinuities	i) No electrical contact ii) All surface of part subjected to toroidal type magnetic field iii) Single process for 100 % coverage iv) Can be automated	i) Laminated core required through ring ii) Type of magnetizing current must be compatible with method iii) Other conductors encircling field must be avoided iv) Large diameter require special considerations
ii) Ball examination	i) No electrical contact ii) 100 percent coverage for discontinuities in any direction with three step process and proper orientation between steps iii) Can be automated	For large diameter balls limited to residual magnetization.
iii) Disk and gears	i) No electrical contact ii) Good sensitivity at or near periphery or ring iii) Sensitivity in various areas can be varied by core or pole piece selection	i) 100 percent coverage may require two steps process with core or pole piece variation or both. ii) Type of magnetizing current must be compatible with part geometry.

Table 1 (Concluded)

Types of Magnetization and Part Details (1)	Advantages (2)	Limitations (3)
D. Yokes		
i) Examination of large surface areas for surface-type discontinuities	i) No electrical contact ii) Highly portable iii) Can locate discontinuities in any direction with proper orientation.	i) Time consuming ii) Must be systematically repositioned in view of random discontinuity orientation
ii) Miscellaneous parts requiring examination of localized areas	i) No electrical contact ii) Good sensitivity to direct surface discontinuities iii) Highly portable iv) Wet and dry technique v) Alternating current type can also serve as demagnetizer in some instances	i) Must be properly positioned relative to orientation of discontinuities ii) Relatively good contact must be established between part and poles iii) Complex part geometry may cause difficulty iv) Poor sensitivity to subsurface type discontinuities except in isolated areas

11.2.2 Indirect Magnetization

Indirect part magnetization involves the use of a preformed coil, cable wrap, yoke, or a central conductor to induce a magnetic field. Coil, cable wrap and yoke magnetization are referred to as longitudinal magnetization in the part.

11.2.2.1 Coil and cable magnetization

When a magnetic material is placed within a current carrying rigid coil of several turns, the magnetic lines of force created by the electric current concentrate themselves in the part and induce a longitudinal magnetic field as indicated in Fig. 5. Parts too large to fit in a fixed coil may be magnetized longitudinally by making a coil of several turns of flexible cable (cable wrap) around the parts (see Fig. 6).

11.2.2.2 Central conductor and threading cable magnetization

Indirect circular magnetization of hollow pieces/parts can be performed by passing the magnetizing current through a central conductor passed through a central opening in the part (see Fig. 7A and Fig. 7B).

11.2.2.3 Induced current flow method

This is a technique of setting up circumferential current flow in large ring specimens by making it, in effect, the secondary of a mains transformer. The optimum flow direction is basically circumferential as shown in Fig. 8.

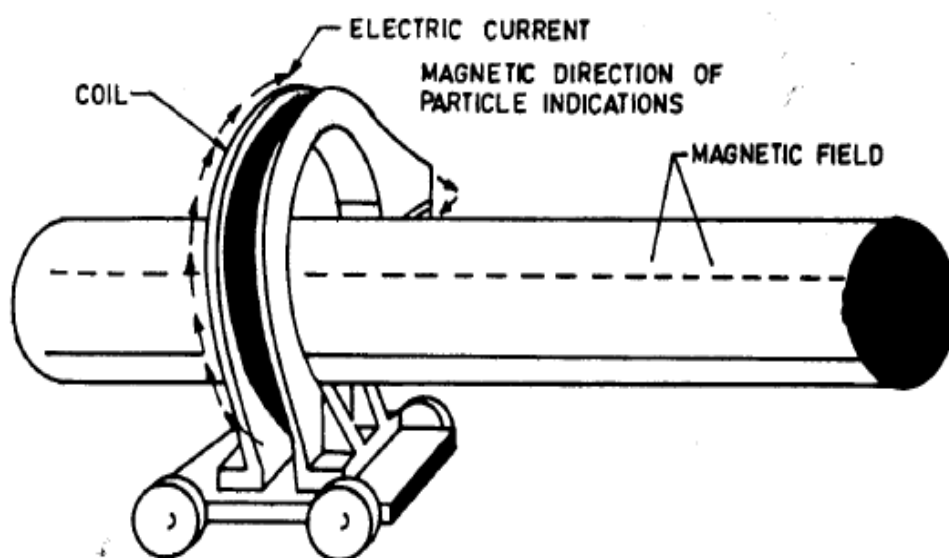


FIG. 5 LONGITUDINAL MAGNETIZATION

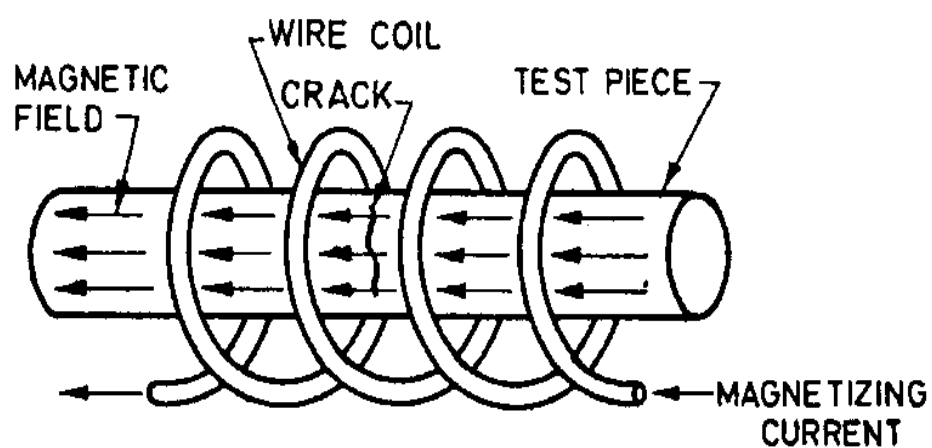
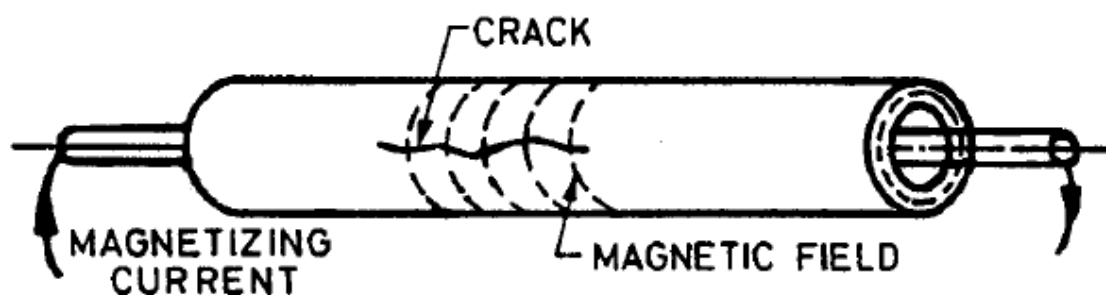
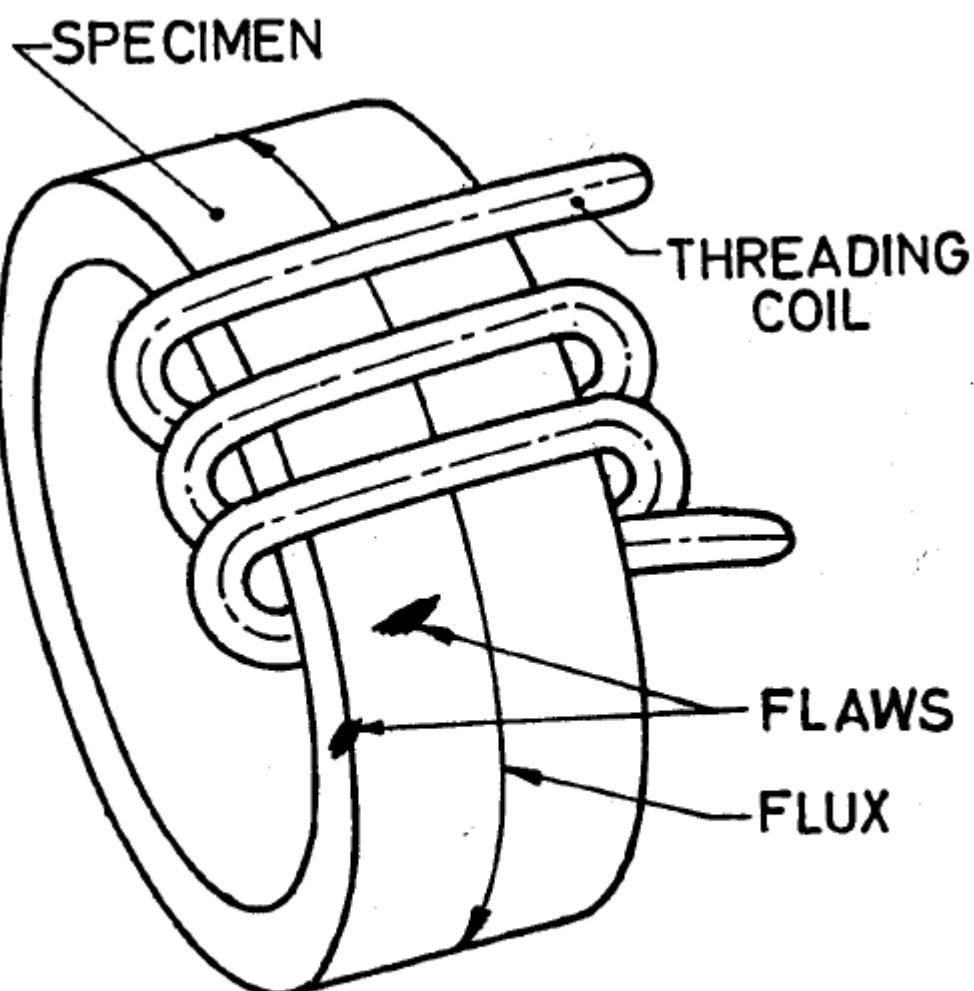


FIG. 6 LONGITUDINAL MAGNETIZATION OF TEST PIECE WITH COIL



7A Circular Magnetization of Passing Current Through a Central Conductor



7B Threading Coil Technique

FIG. 7 CENTRAL CONDUCTOR AND THREADING CABLE MAGNETIZATION

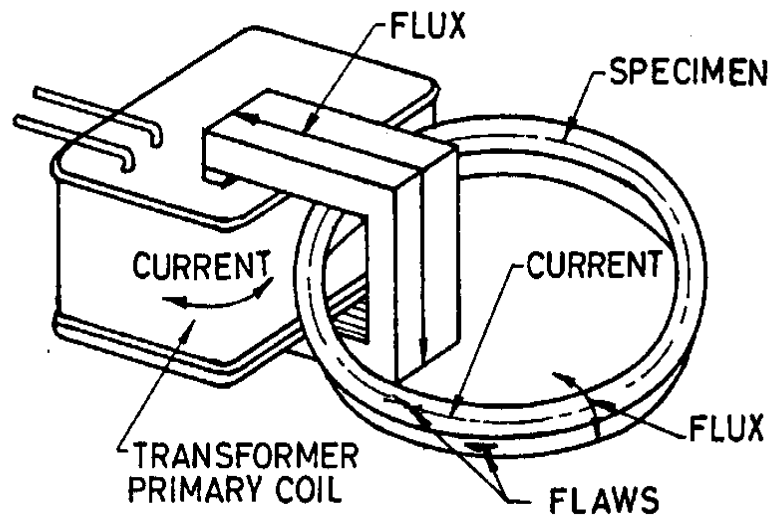
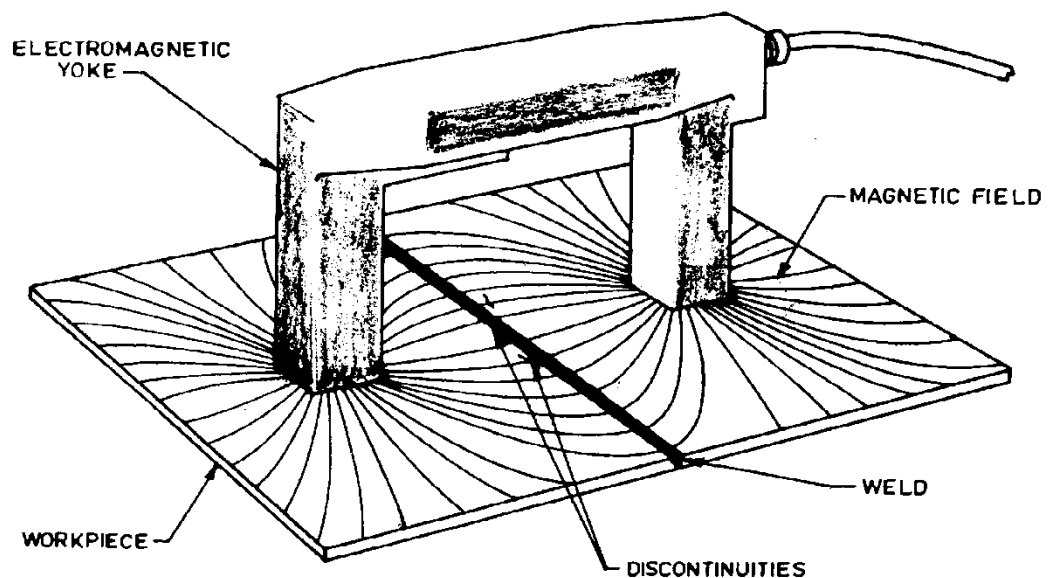


FIG. 8 INDUCED CURRENT FLOW TECHNIQUE

11.2.2.4 Yokes

Yokes are essentially C-shaped electromagnets which create a longitudinal magnetic field between the poles. The dry magnetic particles are generally employed with yoke magnetization technique and are applied while the electromagnetic yoke is energized (see Fig. 9)

Alternating current electromagnetic yokes provide effective means of part magnetization for the detection of surface discontinuities. Half-wave rectified direct current electromagnetic yokes, however, provide an effective means for near surface discontinuities as well.



NOTE — Electromagnetic yoke, showing position and magnetic field for detection of discontinuities parallel to a weld bead. Discontinuities across a weld bead may be detected by placing the contact surface of the yoke next to and on either side of the bead (rotating yoke about 90° from position shown here).

FIG. 9 ELECTROMAGNETIC YOKES

12 CURRENT REQUIREMENTS

To produce satisfactory indications, the magnetic field in the part shall have sufficient strength as mentioned in 9.5. Factors that affect the strength of the field are the size, shape and material of the part, and the technique of magnetization. Since these factors vary widely it is difficult to establish rigid rules for the field strengths for every conceivable part configuration, it is usually best to experiment with the parts having known discontinuities determining the actual requirements. In general, however, following guidelines can be effectively applied to calculate the current value for establishing proper levels of circular and longitudinal magnetization.

12.1 Circular Magnetization

12.1.1 Overall Magnetization with Head and Tail Stock Contact (Head Shot Method)

- For all solid and hollow sections value of FWDC and HW current shall be as given below;
- Alternating magnetizing current can be used at approximately half these values for detection of surface discontinuities;
- For parts with geometric shapes other than round, the greatest cross-sectional diagonal in a plane at right angles to the current flow shall be taken as 'D' in above formulae; and
- The head shot method produces the maximum circular field at the outer diameter (O.D) but a greatly reduced field at the inner diameter (I.D) surface of a part for a given current.

12.1.2 Central Conductor Technique

- Assuming that the central conductor is located centrally, the values given in 12.1.1 may be used taking the outside diameter or perimeter of the component as the criteria for selecting current value. The resulting field is concentric relative to the axis of the part and this permits the entire circumference to be processed at one time. In this technique, the maximum field is obtained at the inside diameter of the part;
- When several bars or cable are passed through the component, the current value shall be reduced in proportion to the number of the windings; and
- Off-setting the central conductor is most often resorted to when the magnetizing current capabilities are lacking, for example in the case of large outside diameter parts. As a matter of convenience if small ring like parts are allowed to rest against their inner wall on a central conductor, this method provides high speed of testing because all parts are magnetized in a single shot. In such instances for the purpose of current calculation as per 12.1.1, part diameter D is taken as diameter of central conductor plus twice the wall thickness of the test part. The entire circumference should be inspected by re-positioning the part(s) on the central conductor allowing for approximately 10 percent magnetic overlap. The distance along the circumference that is effectively magnetized is approximately four times the diameter of the central conductor.

Part Diameter 'D' in mm	Current Value in Ampere/mm of Part Diameter	
	Min	Max
$D < 125$	28	26
$125 < D < 375$	20	28
$D > 375$	4	12

12.1.3 Localized Magnetization**a) Prod technique**

With prod, the field strength of circular magnetization is proportional to the amperage used but varies with the prod spacing and thickness of the section being inspected. The following values are generally recommended:

Sl No.	Section Thickness 't' in mm	Current value in Ampere/mm of prod spacing	
		Min	Max
i)	t < 20	3.5	4.5
ii)	t > 20	4.0	5.0

Prod spacing should not exceed 200 mm. Prod spacing less than 75 mm is usually not practical due to banding of the particles around the prods

b) Yoke techniques

The field strength of yoke can be empirically determined by measuring its lifting power as mentioned in **13.2.2**.

12.2 Longitudinal Magnetization

Longitudinal part magnetization is produced by passing a current through a multi-turn coil encircling the part or section of the part to be examined. The field strength in a part being magnetized in a coil is determined by the ampere-turn of the coil and the length (L) to diameter (D) ratio of the object. The field strength can be calculated as per following formulae:

where

I = Current supplied to magnetizing coil (in amp);

N = No. of turns of coil;

L = Length of the object in mm;

D = Diameter of the object in mm;

R = radius of the coil in mm;

NI_h = Field strength, high; using formula (d);

NI_l = Field strength, low; using formulae (a) or (b); and

α = ratio of the cross-section area of the coil to the cross-section area of object.

Sl No.	Fill factor	Position of object	Field strength (NI) ampere turns (± 10 percent)
(i)	Low	Near/ close to inside surface of coil	$\frac{45000}{L/D}$
(ii)	Low	At the centre of the coil	$\frac{1690 \times R}{6 \left(\frac{L}{D}\right) - 5}$
(iii)	Inter- mediate	Cross section of the coil > twice and < 10 times the cross section of the object	$\frac{NI_h(10 - \alpha) + NI_l((\alpha - 2))}{8}$
(iv)	High	Cross section area of the coil < twice cross section area of the object	$\frac{35000}{\left(\frac{L}{D}\right) + 2}$

When calculating L/D ratio for a hollow or partially hollow part, D may be replaced by with an effective diameter D_{eff} given as below:

For partially hollow parts:

$$D_{eff} = 2 \sqrt{\frac{(\lambda_l - \lambda_h)}{\pi}}$$

where

λ_l = the total cross sectional area of the part;
and

λ_h = the total cross sectional area of the hollow sections of the part.

For hollow cylindrical parts:

$$D_{eff} = \sqrt{[(OD)^2 - (ID)^2]}$$

where

OD = the outside diameter of the cylinder; and

ID = the inside diameter of the cylinder.

13 EQUIPMENT FOR MAGNETIC PARTICLE FLAW DETECTION

13.1 Fixed Equipment

13.1.1 The equipment should be capable of enabling the component or material to be tested in accordance with the specified technique. Current flow sources, such as transformers, giving maximum current values from 2 000 A up to 20 000 A at a safe open voltage between 6 V and 27 V are usually suitable.

13.1.2 The current flow may be derived from either DC, AC, full or HWDC supplies or a combination of these. Rectified AC supplies may be obtained from either single or three-phase mains.

13.1.3 It is recommended that all parts of the equipment should be capable of continuously carrying the rated current available for the apparatus, for an operating cycle of 5 s 'on' and 20 s 'OFF' without overheating.

13.1.4 The equipment should normally, be provided with controls for adjusting the excitation currents either continuously from zero to the maximum, or in steps such that they required current values may be obtained within ± 10 percent of the nominal.

13.1.5 When DC or rectified AC supplies are employed, the equipment should be provided with a current reversing switch to facilitate demagnetization.

13.1.6 The apparatus should be equipped with an ammeter for measuring the current used in any test. For DC supplies, and for rectified AC supplies, it shall be of the permanent magnet moving coil type marked in direct current amperes. For AC supplies it shall be of the moving iron, electrodynamics or induction type marked in rms amperes. Ammeter shall be calibrated for variations not exceeding ± 10 percent of the nominal.

13.1.7 The installation for wet magnetic testing should normally have a reservoir tank to contain the magnetic powder. The tank should preferably be fitted with a powered agitator; but if this is not provided, the tank should be so designed that adequate agitation by a manually operated paddle may be carried out frequently during the operation of the equipment. Air agitation of the powder is not recommended.

13.1.8 Suitable means should be provided for applying the detecting media to the component under test. For liquid media, a powered pump system should be used.

13.1.9 The apparatus shall be equipped with means for firmly clamping the component under test between the current carrying contacts or electromagnet poles.

13.2 Mobile and Portable Apparatus

13.2.1 Mobile and portable apparatus consists basically of a high current low voltage source. Alternatively, a DC battery may be used provided the test requirements are met.

13.2.2 The magnetizing force of a yoke can be tested by determining its lifting power on a steel plate. Alternating current electromagnetic yokes should have a lifting force of at least 4.5 kg with a 150 mm pole spacing. For DC yokes at a maximum pole spacing of 150 mm, a lifting power of 18 kg is recommended.

13.2.3 Unless otherwise agreed, the mobile or portable apparatus should also conform to the requirement of fixed equipment, as specified in **13.1**.

13.3 Ancillary Equipment

The following ancillary equipment should normally be required for magnetic particle inspection:

- a) Bars of various diameters of solid copper, brass or aluminium rod, or of larger sizes plugged aluminium tubing;

- b) Rigid coil of 100 mm, 200 mm, 300 mm and upward in diameter having five or more turns of cables;
- c) Copper gauge face C-Clamps;
- d) Heavy duty welding cables for leads, to be used with the 'prod' technique;
- e) Wooden blocks for supports;
- f) Jigs and fixtures; and
- g) Magnetic field indicators.

13.4 Associated Equipment

The following associated equipment shall also be required:

- a) A demagnetizer of adequate size and power to satisfactorily demagnetize the component under test; and
- b) Suitable sources of white or black light for viewing the flaw indication.

14 INSPECTION MEDIUM (MAGNETIC POWDERS AND FLUIDS)

14.1 The inspection medium shall consist of finely divided ferromagnetic particles, which may be suspended in a suitable liquid medium (wet method) or used in dry powder form (dry method). The main requirements for magnetic powders are high permeability and low retentivity and a very small size and proper shape to be readily mobile over the surface being tested. The colour of the magnetic particles (non-fluorescent) to be used should have adequate contrast with background colour of the surface to be tested for clear identification of flaws.

14.1.1 The dry powder method is more sensitive than the wet method in the detection of near surface discontinuities, but is not as sensitive in detecting fine surface discontinuities. It is also convenient to use in conjunction with portable equipment for the inspection of large areas or for field inspection. The dry powder method is, therefore, often used for the inspection of large parts, such as large castings, forgings or weldments or parts with rough surfaces. It is not normally used for the inspection of smaller parts, such as automotive or aircraft parts, in which case the wet method with stationary equipment is usually more convenient and effective.

14.2 Dry Powders

Dry powders are designed to be used as supplied and are applied by spraying or dusting directly on to the surface of the part being examined. Dry powders may also be used under extreme environmental conditions. They are not affected by cold; therefore

examination can be carried out at temperatures that would thicken or freeze wet baths. Dry powders are also heat resistant and can be used up to 315 °C. Generally dry powders are available in light grey, black, red, or yellow colours. The choice is based on maximum contrast with the part to be examined. These materials are not generally fluorescent, and examination is done under white light. The dry powders should meet the requirements of IS 6410.

14.3 Wet Powders

Wet magnetic particles are designed to be suspended in a vehicle such as water or oil at a given concentration for application to the test surface by flowing, spraying or pouring over the surface, or the specimen under inspection may be immersed in an agitated bath of the inspection medium. Wet magnetic particles meeting the requirements of IS 6410 should be used in this method. Two types of wet magnetic particles may be used as follows:

a) Fluorescent Magnetic Particles

The particles used in the wet fluorescent magnetic particles bath are coated with a dye which caused them to fluoresce brilliantly when exposed to near black light. The purpose of the dye is to provide maximum contrast between the indications and their background so that fine discontinuities may be detected; and

b) Visible Magnetic Particles

The visible magnetic particle normally used in wet-baths are either reddish or black and are observed under normal white light. There is no difference in sensitivity with respect to dry powder method, and the colour should be so selected as to provide the best contrast against the background of the part being inspected.

14.3.1 Liquid Vehicle

a) Water Vehicles

Water may be used for suspending wet magnetic particles provided suitable conditioning agents are added which provide proper wet dispersing, in addition to corrosion protection to the parts being tested and the equipment in use. Water vehicle is safe to use as it is non-flammable.

b) Oil Vehicles

The oil used in preparing the bath is a light, well-refined petroleum distillate of low sulphur

content, preferably treated to reduce any unpleasant odours, and having approximately the following characteristics:

Viscosity (Kinematic at 38 °C) 3 cSt, *Max*

Flash-point (closed cup) 93 °C, *Min*

NOTE — Stoke is the CGS unit of kinematic viscosity, [1centiStoke (cSt) = 10^{-6} m²/s].

Where oil is used as a vehicle for fluorescent particles, it should have the minimum amount of natural fluorescence and should not degrade suspended particles. Uniform dispersion of magnetic particles in oil vehicles and corrosion protection to parts and equipment are the chief advantages of the use of oil vehicles. Principal disadvantages are flammability. Commonly employed oil for suspending both fluorescent and non-fluorescent magnetic particles is kerosene.

14.3.2 Bath Strength

The concentration of magnetic particles in the bath should be maintained at the proper level if the inspection results are to be reliable and consistent. The concentration is periodically checked by taking a 100 ml sample from a well stirred bath and allowing it to settle for 30 min in pear-shaped centrifuge tube. The volume settling out at the bottom is indicative of the particle concentration. With red or black material, the recommended concentration from a 100 ml sample is 1.2 ml to 2.4 ml. For fluorescent material the recommended concentration is 0.1 ml to 0.4 ml. Care should be taken to see that the inspecting medium is not contaminated with grease, oil, water or foreign matter. If a clear line of demarcation is seen between the sediment and the liquid when the medium is allowed to settle in the centrifuge tube, it may be taken as being free from contamination.

15 TEST PROCEDURE

15.1 General

All tests consist of the following processes which should be carried out in the given order:

- a) Surface preparation;
- b) Initial demagnetization;
- c) Degreasing and cleaning;
- d) Applying the excitation current for generating the magnetic field;
- e) Applying the detecting media;
- f) Viewing;

- g) Marking position of indications;
- h) Assessment and recording the nature of flaws;
- j) Demagnetization;
- k) Repetition of the tests, if necessary;
- m) Cleaning; and
- n) Preparation for storage

15.1.1 Selection of Test Method

A suitable test technique should be selected as per the recommendations given in Table 1, for examination of a component with a specific geometric shape.

15.2 Surface Preparation

15.2.1 The surface to be inspected shall be clean, dry and free from rust, oil, scale, excessive slag and other extraneous matter which may interfere with efficient inspection. Machined or plated surfaces normally do not require any preliminary surface treatment other than degreasing. However rough surfaces such as very rough weld bead make the interpretation difficult due to mechanical trapping of the magnetic powder thereby producing false indications. In such cases surface preparation by wire brushing, sand blasting, grinding, machining or other suitable method is necessary.

15.2.2 Painted Parts

- a) Parts, which are to be painted, should preferably be tested before application of the paint. Otherwise, subject to mutual agreement between the manufacturer and the buyer, paint shall be removed locally, so as to provide adequate contact areas for the current flow tests. Other painted areas will only require degreasing; and
- b) Poor contrast is likely to be obtained if the colour of the paint is the same as that of the particles in the ink to be used. In such cases, an approved contrast aid may be applied. A contrast aid is normally a thin white adherent coating which is compatible with the ink and readily removed after use.

15.2.3 Loose rust and scale should be removed from components before testing by suitable mechanical or chemical methods.

15.3 Initial Demagnetization

All components should be demagnetized before testing, in order to release any adhering magnetic

swarf and to remove any magnetic fields such as those which cause magnetic writing.

15.4 Degreasing and Cleaning

All components should be thoroughly cleaned before testing, as adhering grease and dirt may mask the defects and also contaminate the ink.

15.4.1 For cleaning unassembled parts, it is essential to subject them to a degreasing operation, followed by a mechanical wiping operation to remove adherent solid residues.

15.4.2 When a component is to be tested in-situ in a structure, the following cleaning procedure is recommended:

- a) The heavier soil should be removed using a clean rag or cotton waste moistened with a suitable solvent preferably white spirit or paraffin. Liquid chlorinated hydrocarbons are hazardous and should not be used.
- b) The cleaning should be continued with a fresh lint-free rag and fresh solvent, until a satisfactory clean surface is obtained.

15.5 Application of Magnetizing Current

Magnetic flux should be generated in the component by any one of the methods specified in 10, which is suitable for the individual requirement. Depending upon the sequence of application of the magnetic particles on the test object, with respect to magnetizing current there are two variations in the method as follows.

15.5.1 Continuous Method

In this method, the inspection medium is applied to the surface under inspection while the full magnetization current is flowing.

15.5.2 Residual Method

In this method, the inspection medium is applied to the surface under inspection after the magnetization current has been turned off. This method may be used, when specified, on parts having a relatively high magnetic retentivity. It depends upon the residual magnetic field in the part to produce indications, and is usually limited to the detection of surface cracks. Residual method offers some advantage when numerous

small parts of high retentivity materials such as high carbon or hardened steel are being tested by this method. Parts may be magnetized rapidly and then immersed in a wet bath, or powder applied; therefore reducing the inspection time as compared to the continuous method.

15.6 Application of the Detecting Media

Unless residual magnetization methods have been agreed upon, the detecting medium should be applied immediately before and during excitation. The application should stop before the magnetization current is switched off. Sufficient time, not less than 3 s, should be allowed for the indications to build up before moving or examining the component under test.

15.6.1 Dry Powder Application

Dry powder when used, should be applied with a suitable blower in a manner that uniform dust cloud settles on the test part surface. The dry powder should be applied when the magnetization force is ON. Excess powder if any must be removed by dry air current just sufficient enough to remove the powder which may interfere in the evaluation of indications.

15.6.2 Wet Powder Application

Wet powders visible or fluorescent suspended in suitable vehicle may be applied by spraying, flowing or immersion technique. The particle bath should be suspended in a stable form before the magnetizing current is turned OFF. Care should be taken that fine and weakly held indications are not washed away.

15.7 Viewing Conditions

15.7.1 The lighting used for inspection purposed should be adequate without creating strong shadows or highlights. There should be an even illumination to a level of not less than 1 076 lux daylight or artificial light to permit proper evaluation of the indications revealed on the test surface.

15.7.2 When using fluorescent inks and powders, the inspection area should be darkened and level of illumination due to white light should not exceed 20 lux. The inspection should be carried out under ultraviolet radiation with a predominant wave length of 365 nm (3 650 Å), that is, 'black light' conditions. The intensity of blacklight at the test surface shall be not less than 1 000 µW/cm² and unnecessary

reflection of ultraviolet radiation from the test surface should be avoided.

15.8 Marking of Flaws

Where necessary, flaws shall be indicated by an approved means, such as red-wax pencil.

15.9 Assessment of Indications

The indications obtained by magnetic particle flaw detection are all of a general form – a ‘pilling up’ of the magnetic particles at the lines of flaws, variations being of size, shape and position. The accurate interpretation of flaw indications is a matter requiring considerable experience. The service condition of a component should always be borne in mind when specifying flaws. The common flaws are easily identifiable, but in some cases, false indications may be obtained. Typical examples of these are:

- a) Grain flow indications caused by over-magnetizing;
- b) Over heavy indications on small diameters or around holes caused by magnetizing when using the magnetic flow method;
- c) Indications caused by abrupt changes of section, for example, indications on the outside diameter of a tube shaft caused by internal key way or splines;
- d) Magnetic ‘writing’ caused by the rubbing of another magnetized part during handling or the use of magnetized scribe; and
- e) Indications occurring at the interface of two metals of differing magnetic permeability which have been welded together.

15.9.1 The most common types of imperfections, that are identified by magnetic particle inspection, are grinding cracks, cracks caused by incorrect heat-treatment, seams due to rolling flaws, subsurface inclusions and shrinkage cracks in casting.

15.10 Demagnetization

15.10.1 Ferromagnetic components which have been tested by magnetic particle flaw detection method, often remain magnetized for a considerable time after testing. This may be exceedingly troublesome if the component is to be built into machinery or is likely to operate in close proximity to sensitive electrical instruments. In the former case the local poles formed at projections and extremities will attract ferrous particles, causing excessive wear due to abrasive effects, or making machining

extremely difficult owing to the pick-up of metal chips, by clinging to the tool and causing scratching and other damage to the metal surface. Strong magnetic field may blow the weld metal as it is deposited. In aircraft construction, steel parts in the proximity of the aero plane compass should be demagnetized to eliminate any effect on the compass. Demagnetization takes place automatically if the specimen is heated above the transformation temperature (Curie point). But, for the majority of specimens which are tested in finished condition, demagnetization methods which will not interfere with the metallurgical condition of the material will have to be used. However, complete demagnetization is difficult if not impossible to obtain, thus the process is limited to reducing the residual field in specimens that must be demagnetized to an acceptable level specified in drawings specification or purchase order. For general engineering application interference caused by magnetism equal to or less than $0.1 \times 10^{-3} \text{ T}$ (1 G) is negligible; therefore it is considered as an acceptable level for the residual magnetism.

15.10.2 For a longitudinally magnetized component, it is easy to measure the residual magnetism since flux leakage takes place at both the poles. However, a part may retain a strong magnetic field after having been circularly magnetized and exhibit little or no external evidence of this external field as the flux lines do not leave the part. Therefore, before demagnetizing circularly magnetized article, it must be magnetized longitudinally with a stronger longitudinal field so that the residual field will be in longitudinal direction.

15.10.3 Demagnetization is usually accomplished by subjecting the specimen to a magnetizing force that is continually reversing in direction and decreasing in strength so that the hysteresis loop is reduced to virtually zero. A simple and effective method of accomplishing this is to insert the piece in the field of an alternating-current solenoid and gradually to withdraw it from the field. It is important that the demagnetizer be set up with its axis in a magnetic East-West orientation.

15.10.4 Many modern flaw detectors are provided with continuous step less control for the A.C circuit and these may be used for demagnetization as follows:

- a) Current from the flaw detector may be passed through a coil of two or three turns of heavy

cable wound round the specimen and gradually reduced to zero; and

- b) Alternatively, current may be passed directly through the specimen, as when testing by the current flow method, and reduced to zero by means of the control.

15.10.5 Direct-current demagnetization is usually accomplished by repeated reversal of the current while it is being progressively weakened.

15.11 Cleaning

After testing and acceptance, all components shall be cleaned to remove all traces of detecting ink, contrast aid, if used and temporary marking, if applied, this may be carried out by wiping or washing with solvent like white spirit, or by complete immersion in approved degreasers agent.

15.12 Preparation for Storage

A suitable temporary protective, as agreed to between the contracting parties, may be applied to the component after cleaning to prevent corrosive attack.

16 RECORDING OF TEST DATA

The following data should be recorded at the time of each test for future reference:

- a) Name of organization and location and the date of test;
- b) Nomenclature, identity and dimensions of the part under test;
- c) Operation stage as per process sheet (that is raw material, before or after heat treatment, before or after machining etc);
- d) Test procedure/written instruction use;
- e) Description of equipment, testing consumables and detection media used;
- f) Magnetization techniques, type of current and its values, prod spacing and L/D value used;
- g) Surface conditions on the job and viewing conditions on the job;
- h) Method of recording the indications as specified in 16;
- j) Nature and type of indications, statement of whether they meet acceptance criteria and test results; and

- k) Name, qualification and signature of the personnel performing the test.

17 RECORDING INDICATION

17.1 When the examination of a specimen has been completed, flaws should be marked with a pencil, paint or some other suitable means.

17.1.1 Where permanent records of the indications are required, these may be obtained either by taking photograph of the indications or by one of the following methods:

- a) The specimen should be allowed to dry completely. A piece of transparent adhesive tape should then be pressed over the defect indication, and immediately peeled off. This record may be preserved by covering the adhesive surface with transparent paper; and
- b) A piece of tracing cloth is given an even coating of gum, allowed to become almost dry, and then pressed over the flaw indication on the defective component. On stripping all the indications come away with the tracing cloth. When the latter is quite dry, it may be used for marking blue prints of the indications, if necessary.

18 EVALUATION OF SYSTEM PERFORMANCE/SENSITIVITY

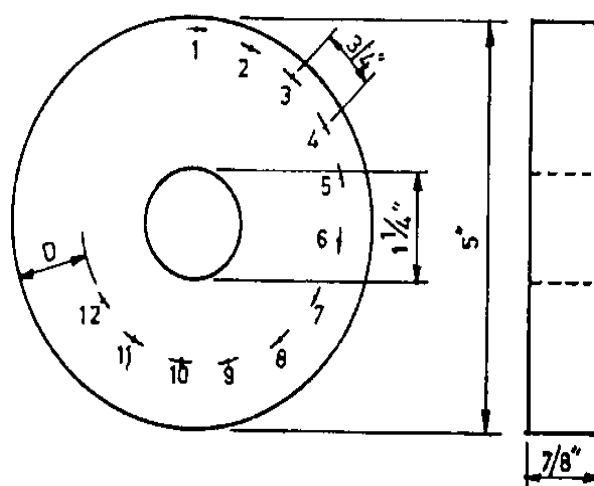
To evaluate the overall performance/sensitivity of the flaw detecting machine and medium, it is desirable that some form of test is conducted, preferably daily, before routine work is commenced. For this purpose, a test piece of some size and shape known to contain defects or an artificial test block may be used.

18.1 Test Ring Specimen

This specimen (*see* Fig. 10) should be fabricated from tool steel cut from annealed round stock having hardness in the range of 90 HRB to 95 HRB. Using a central conductor magnetizing technique overall performance and sensitivity of the magnetic flaw detector and the medium may be evaluated (*see* Table 2, 3 and 4).

18.2 Magnetic Field Indicators

A magnetic field indicator (*see* Fig. 11) may be used for checking the adequacy and direction of the part magnetization. When fixed on the surface of the part under test and magnetized simultaneously this indicator will indicate suitable flux or field strength if a clearly defined line of magnetic particles forms across the copper face.



Hole	1	2	3	4	5	6	7	8	9	10	11	12
Diameter	07	07	07	07	07	07	07	07	07	07	07	07
"D"	07	14	21	28	35	42	49	56	63	70	77	84

FIG. 10 RING SPECIMEN WITH ARTIFICIAL SUB-SURFACE DISCONTINUITIES

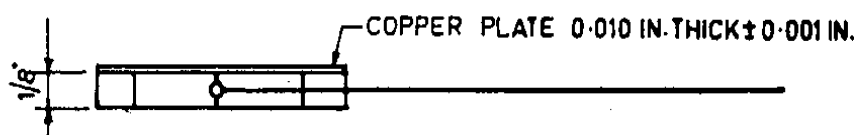
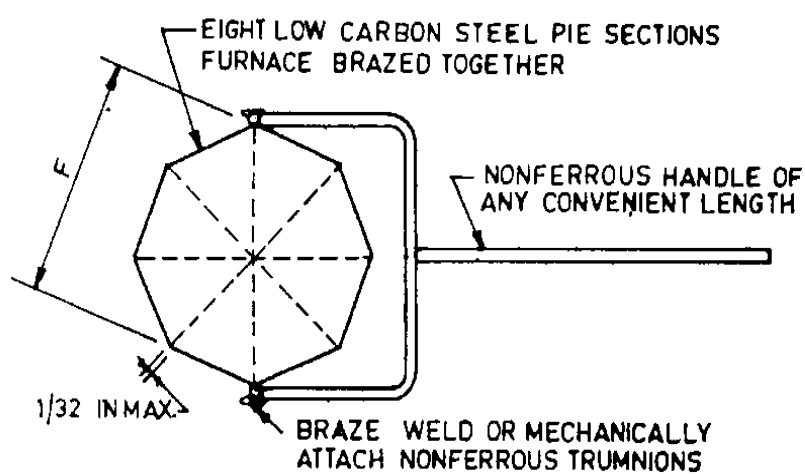


FIG. 11 MAGNETIC FIELD INDICATOR

Table 2 Advantages and Limitations of the Various Types of Magnetizing Current
(Clause 18.1)

Sl No.	Type of Current and their Use	Advantages	Limitations
(1)	(2)	(2)	(3)
i)	Direct Current (DC) Detection of both surface and sub-surface discontinuities. Primarily used for sub-surface and relatively small operations.	Maximum penetration of flux into object permitting indications of sub-surface discontinuities.	Difficult to demagnetize. Battery maintenance. Fixed voltage. Now-a-days rarely used in industries.
ii)	Alternating Current (AC) Detection of surface discontinuities. Extensively used for the demagnetization of parts after examination.	AC results in a 'skin effect' that confines the magnetic field to the surface of an art and thus making it most sensitive for detecting surface discontinuities. High magnetic particle mobility is attributed to its pulsating characteristics. Relatively easy to demagnetize.	Shallow penetration of flux making AC ineffective for sub-surface discontinuities.
iii)	Half-Wave Rectified Alternating (HWAC) Detection of both surface and sub-surface discontinuities. Most sensitive for sub-surface discontinuities. Primarily used with prod type examination associated with portable and mobile type equipment.	Higher flux densities for the same average current. Full penetration of flux into object. Additional particle mobility in conjunction with dry powder. Can be easily obtained from AC power supply by addition of rectifier and switch. Suitable for field work.	Relatively difficult to demagnetize.
iv)	Full-Wave Rectified Direct (FWDC) Suitable for the detection of both surface and sub-surface discontinuities. Primarily used for inspection of large components on wet horizontal or stationary power packs.	Current of very high magnitude such as 6 000 to 20 000 A are easily obtained. Detection of surface and sub-surface discontinuities is possible.	Large power packs. Not suitable for field work.

Table 3 Ring Specimen Indication with Wet Particles
(Clause 18.1)

Sl No.	Type of Wet Suspension Particles	Magnetizing Amperage (FWDC)	Minimum Number of Sub-Surface Holes Indicated
(1)	(2)	(3)	(4)
i)	Fluorescent or non-fluorescent	1 400 2 500 3 400	3 5 6

Table 4 Ring Specimen Indication with Dry Particles
(Clause 18.1)

Sl No.	Magnetizing Amperage (FWDC)	Minimum Number of Sub-Surface Holes Indicated
(1)	(2)	(3)
i)	1 400	4
ii)	2 500	6
iii)	3 400	7

ANNEX A
(Foreword)

CHEMICAL COMPOSITION

Non-Destructive Sectional Committee, MTD 21

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002

Telephones: 2323 0131, 2323 3375, 2323 9402

Website: www.bis.gov.in

Regional Offices:

	Telephones
Central : 601/A, Konnectus Tower -1, 6 th Floor, DMRC Building, Bhavbhuti Marg, New Delhi 110002	{ 2323 7617
Eastern : 8 th Floor, Plot No 7/7 & 7/8, CP Block, Sector V, Salt Lake, Kolkata, West Bengal 700091	{ 2367 0012 2320 9474
Northern : Plot No. 4-A, Sector 27-B, Madhya Marg, Chandigarh 160019	{ 265 9930
Southern : C.I.T. Campus, IV Cross Road, Taramani, Chennai 600113	{ 2254 1442 2254 1216
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